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International Council for
the Exploration of the Sea

C.M. 1974/C:30
Hydrography Committee

On the Problem of the Determination of the Sedimentation in Semienclosed Sea Areas

by

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When one tries to construct balance models for different parameters in an estuary, one generally calculates the discharge from land directly and through rivers, atmospheric transports and inflows and outflows through the straits to the open sea. Some values can be calculated from direct measurements, others have to be derived from statistical information of sewage and industrial waste discharge figures. In- and outflows can be calculated from the water balance of the area and concentration measurements in the straits.

The most difficult parameter to estimate is the sedimentation, which removes a part of the discharged matter from the system. The sedimentation is generally calculated as the difference between discharged matter including inflow from the ocean, and the matter removed by the outgoing water in the strait.

Sediments are formed partly through direct sedimentation of inorganic and organic particles in river water brought into the sea or through precipitation of dissolved inorganic and organic matter from the fresh water of the rivers, when it mixes with salt water in the estuaries, and partly through sinking of dead organic matter formed in the sea itself. Other sources may be wind transported matter from land and matter in the atmospheric precipitation. We have also the inorganic matter originating from life in the sea, e.g. coral reefs, shells of different plankton organisms and mussels etc. There is further a chemical precipitation of matter at the sea bottom e.g. calcium deposits, manganese nodules and phosphates. In stagnant water containing hydrogen sulfide precipitation of metal sulfides may occur. Because organic matter is oxidized also in the upper parts of the sediments, there may be a leakage of matter from the sediments into the water phase. In stagnant water e.g. phosphate is released from sediments if hydrogen sulfide is present in the water.

When sedimentation is estimated as the difference between matter added to the area and matter removed from it, it is not possible to draw any conclusions about where the sedimentation occurs or if a part sediments in shallow water and the rest in deep water or if anything is released from the bottom.

In every case a part of the matter is lost to the sediments and buried so deep that it is totally removed from the system. Only areas with very strong currents will have bottoms completely free from sediments.

The difference reported as sedimentation in balance models is of course very uncertain. The value is only rough and approximate. The value used in the balance may in some cases be close to guesses and in different works from the same area the values used by different authors may show large differences.

I will here discuss some models of the Baltic and the Black Sea where nutrient balances have been calculated. Such models can of course be made for other sea areas too. First I will show two balance models of phosphorus in the Baltic, the first by Fonslius (1972) and the second by Sen Gupta (1974). Fonselius (Fig. 1) arrives at a sedimentation of 18 500 tons of P/year in the Baltic. He does not try to estimate how much of this amount actually is sedimented in shallow and deep water. He also puts a question mark on the dissolution rate in the stagnant bottom water. Sen Gupta (Fig. 2) arrives at 30 400 tons of P as a total amount and also leaves open the question about how much actually is sedimented into the different parts. It is easy to see that the difference between the two estimations of the sedimentation mainly is caused by the difference in the estimated supply of phosphorus from land. It has nothing to do with the real sedimentation rate. The supply from land (communities) has been calculated by means of person equivalents, which have been estimated from the content of P in sewage water. From such figures it is not possible to tell how much of the phosphorus actually is reaching the ocean basin. The main part may be lost in close neighborhood to the discharge area.

Voipio (1969) has also discussed the phosphorus balance of the Baltic, but he used too crude estimations for the different transports to get any difference between sedimentation and dissolution from the bottom (Fig. 3). Voipio's calculations , however, are founded on quite a different and interesting approach. Voipio assumes that phosphorus is precipitated as iron phosphate and estimates by means of iron values in river water the sedimentation to be around 10 000 tons P/year. He also computes the amount dissolved in stagnant water by help of the phosphate values in the stagnant water from Fonselius'work (1967) and arrives at almost the same figure as for precipitation with iron (10 000 tons P/year). But Voipio points out that sedimentation as e.g. organic matter is not included in his balance and that phosphorus buried into the sediments in an oxidizing environment will remain there. Because runoff and outflow are of the same order of magnitude and therefore balance each other, the sedimentation in other forms than iron phosphate will be equal to the inflow through the Belts or less than 10 000 tons P/year.

Fonselius (1974) has also tried to calculate the sedimentation in the Black Sea using available figures from the literature for river transport and phosphate concentrations and measured values for the exchange through the Bosporus (Fig. 4). In this paper no person equivalents have been used for the discharge from communities and no industrial discharge data have been included. Therefore the sedimentation probably is too low. It has to be observed that sediments even from the deepest parts contain phosphorus in spite of the fact that P should be released from the sediments. We have to remember that only phosphate released from the organic matter will dissolve in reducing water and that the part bound to organic matter only slowly is oxidized in the absence of dissolved oxygen and that therefore a part of it will be buried deep enough in the sediments to be retained there. (Hirst 1974). Manheim et Cham (1974) has shown that the phosphorus content of interstitial water from deep sea cores from the Black Sea is lower than the concentration in the water close to the bottom in the same area.

Direct measurements of sedimentation is a very difficult task. The sedimentation depends on currents and other water movements and on the bottom configuration. Therefore the sedimentation on an uneven bottom may vary from spot to spot. Parts of the bottom may be free from sediments (e.g. in areas with strong tides). In holes, basins and trenches the sedimentation may be extremely high. It is also difficult to estimate what a real sediment surface is. There is often a zone or intermediate layer containing temporarily sedimented matter. This layer may be diffucult to define and may be very diffuse. Most of the devices constructed for direct measurements will act more as traps for particulate matter than as sedimentation measurers. If a jar or bottle is placed on the bottom or at a certain depth by help of e.g. a rope or wire, it will act as a trap for particles which will sediment inside in the calm water. In that way one may get up to ten times too high values. On a smooth surface we may get the real sedimentation, but even here the surface of the device may be of importance for retaining sediment particles. The difficulty is, however, how to get up the device without disturbing the sediment surface. Especially in depths unaccessible for divers, very complicated devices have to be constructed in order to recover the sample.

The use of corersor bottom grabbers which leave an undisturbed surface may of course be used, but generally it will not be possible to see or estimate the thickness of an annual sediment layer in the uppermost part. This is necessary for getting the yearly sedimentation during recent years, which is of interest in pollution studies.

More effort has to be put on the sedimentation problem, in order to obtain better models for sea areas.

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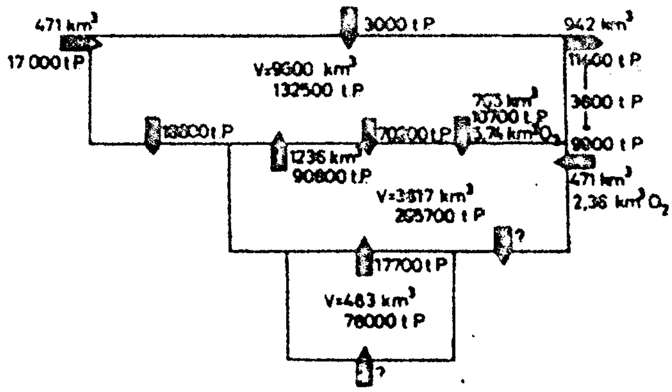
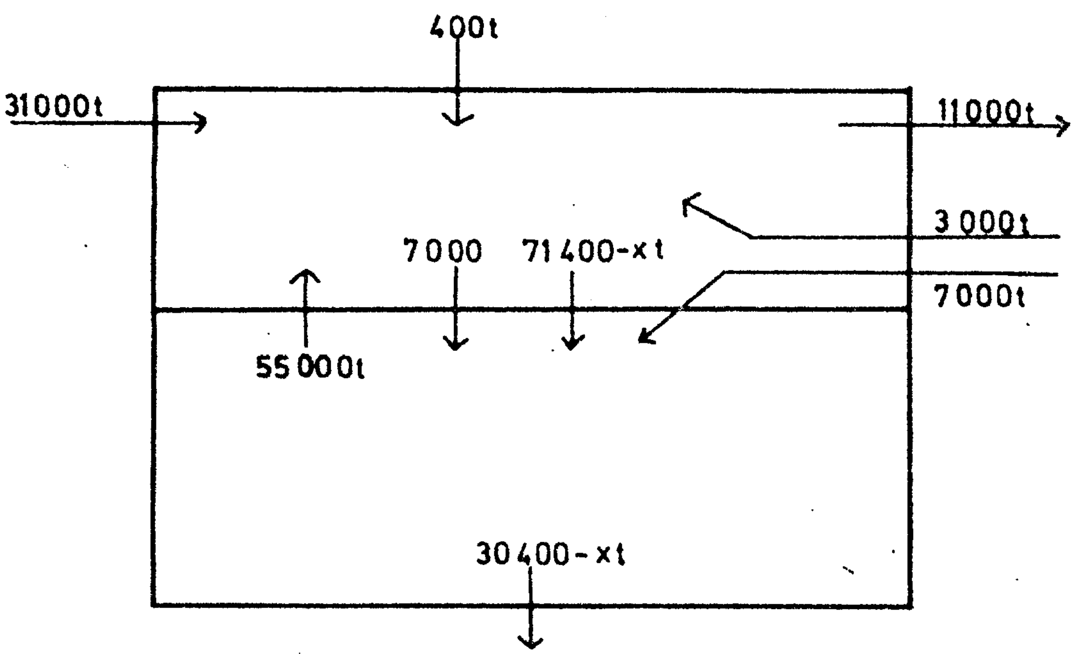
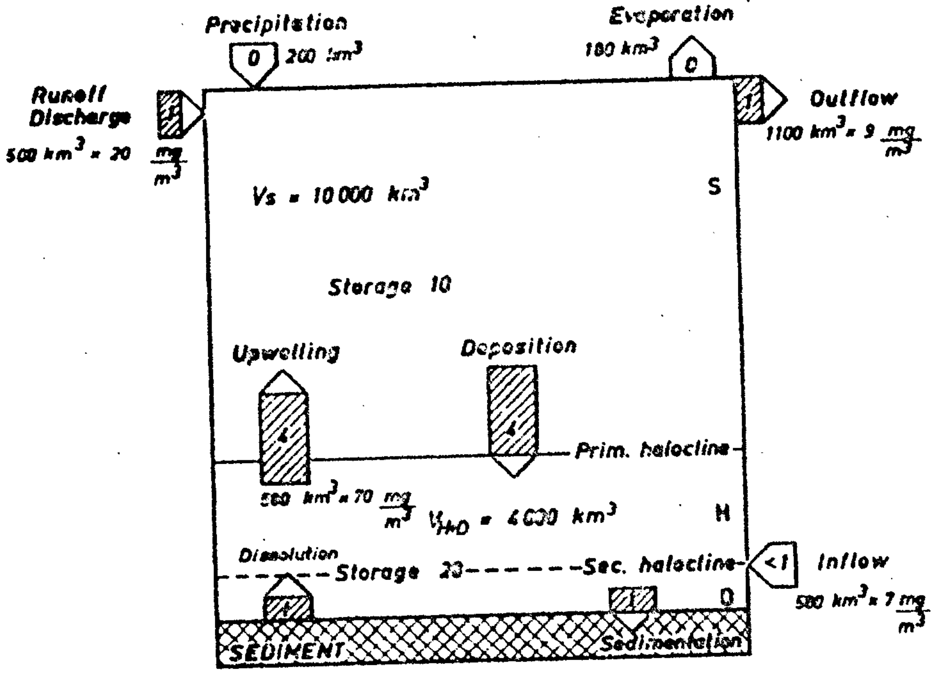


Fig. 1 A model of the phosphorus balance in the Baltic.



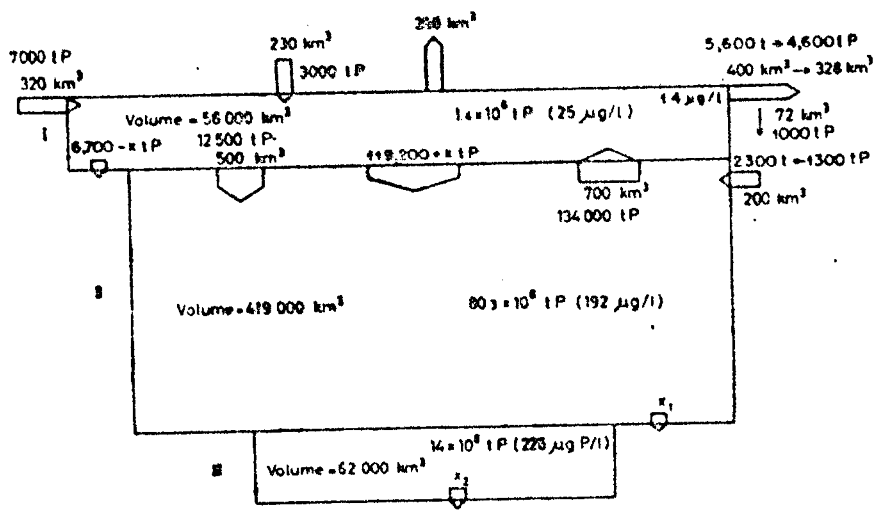
Phosphorus Balance of the Baltic according to the budget of Sen Gupta

Fig.2



The phosphorus cycle and balance in the Baltic Sea. The numbers without dimensions refer to the masses of phosphorus in 10[10] g of P.

Fig. 3



—Model of phosphorus balance of Black Sea. Basin has been divided into three boxes: I, surface water (water above halocline); II, deep water; III, bottom water.

Fig. 4